On line non-contact gas analysis on an industrial scale

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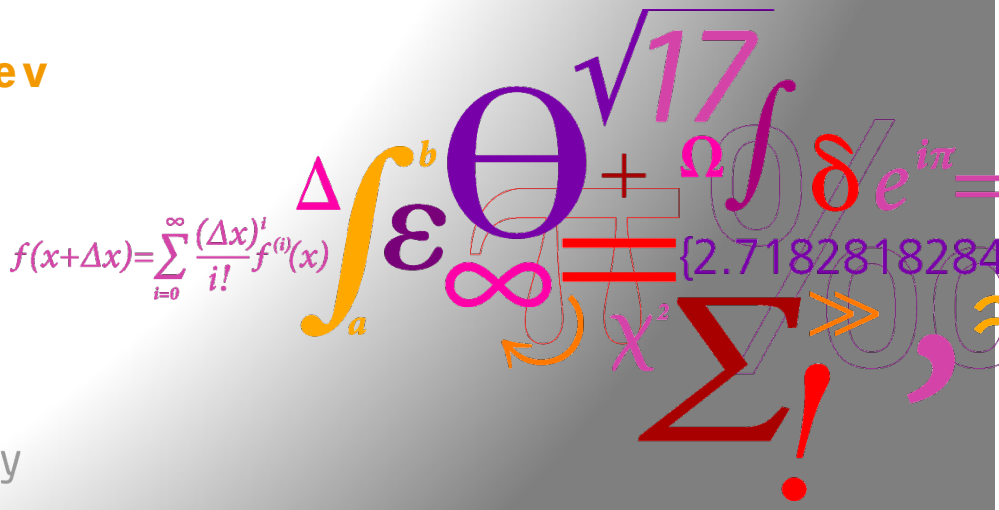
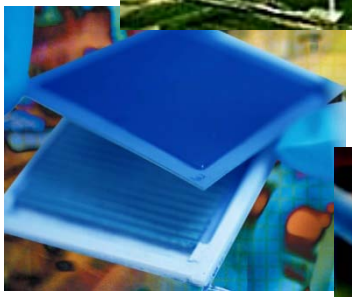


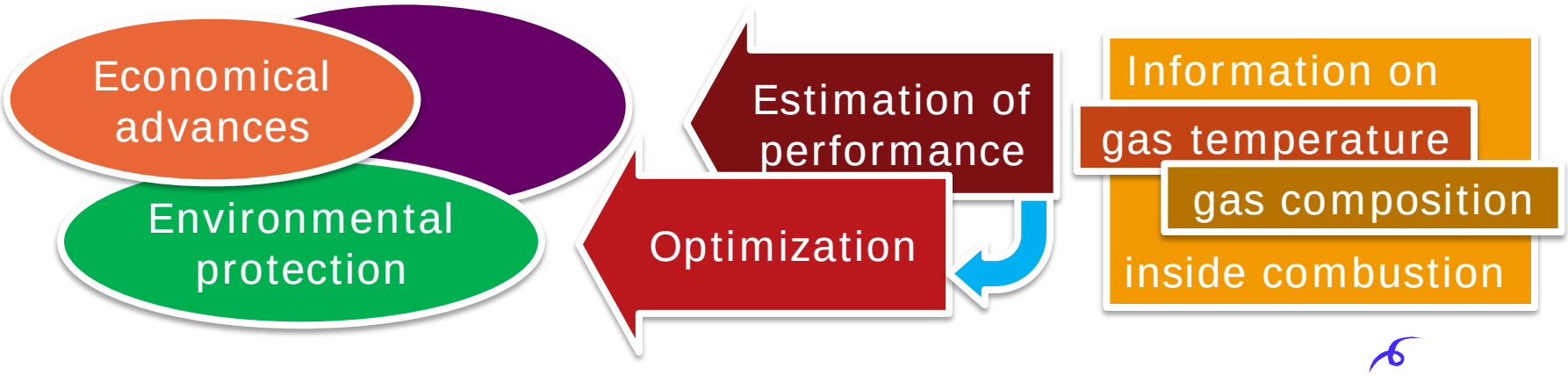
DENMARK
Risø DTU
National Laboratory for Sustainable Energy

Risø DTU: National Laboratory for Sustainable Energy

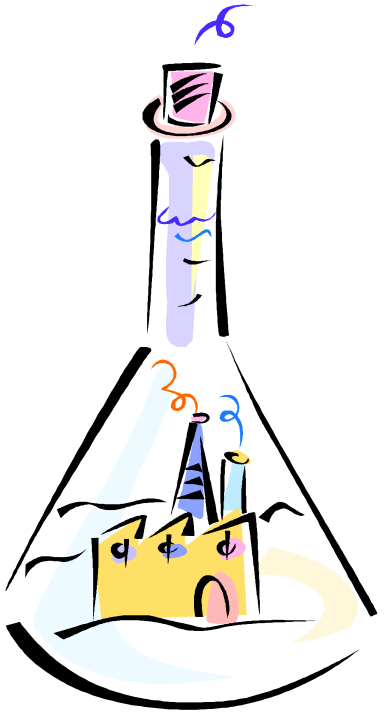
- **Technology for sustainable energy supply**
  - Wind energy
  - Fuel cells and hydrogen
  - Bioenergy
  - Coming energy technologies:
    - Fusion
    - Solar cells
    - Cleaner energy technologies and energy conservation



Introduction: Optical Diagnostics Group

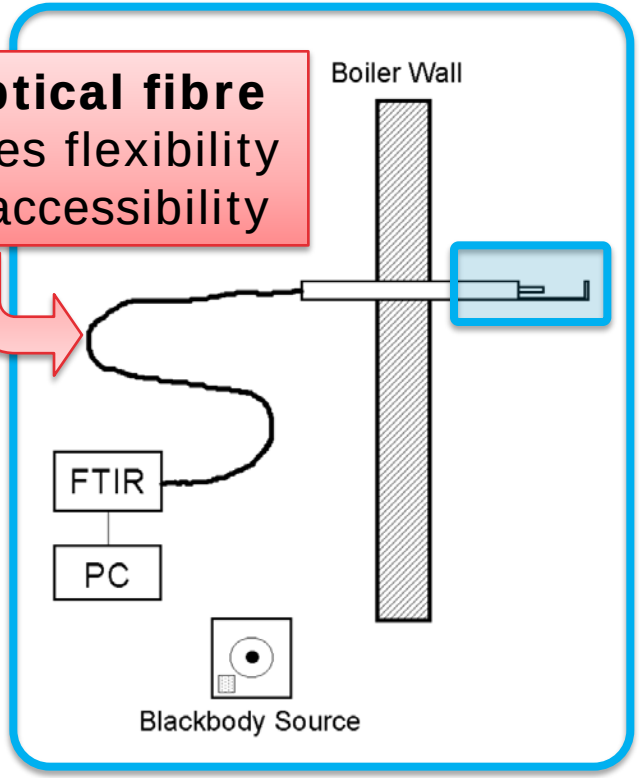


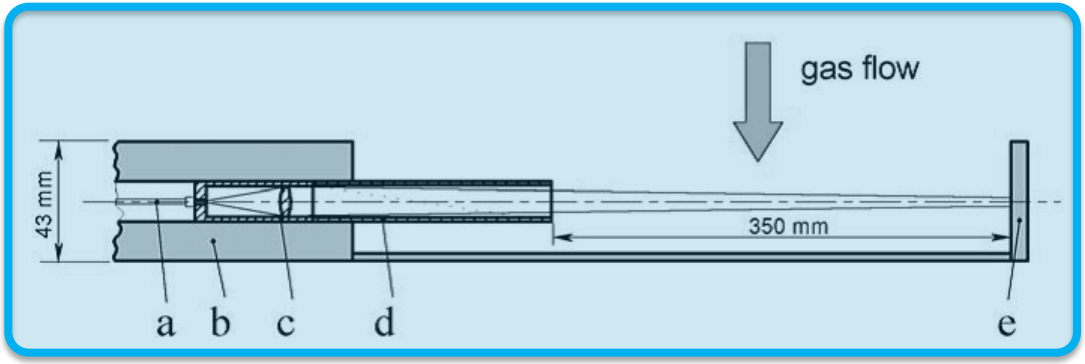
- **Development of methods and equipment for on-line optical measurements of gas temperature and species concentrations**
  - such as O_2, NO_x, SO_2, CO, CO_2, H_2O and C_xH_y
  - in flames or hot gas flows
  - inside boilers, exhaust pipes, engines, etc.
  - using IR/UV emission/absorption spectrum measurements
- **Investigation of spectral properties of gases at high temperatures**
  - This allows to improve quality of spectrum modeling and thus to increase accuracy of on-line measurements
- **Calibration of temperature and infrared measuring equipment (accredited by DANAK)**



Optical instrumentation

Optical fibre gives flexibility & accessibility



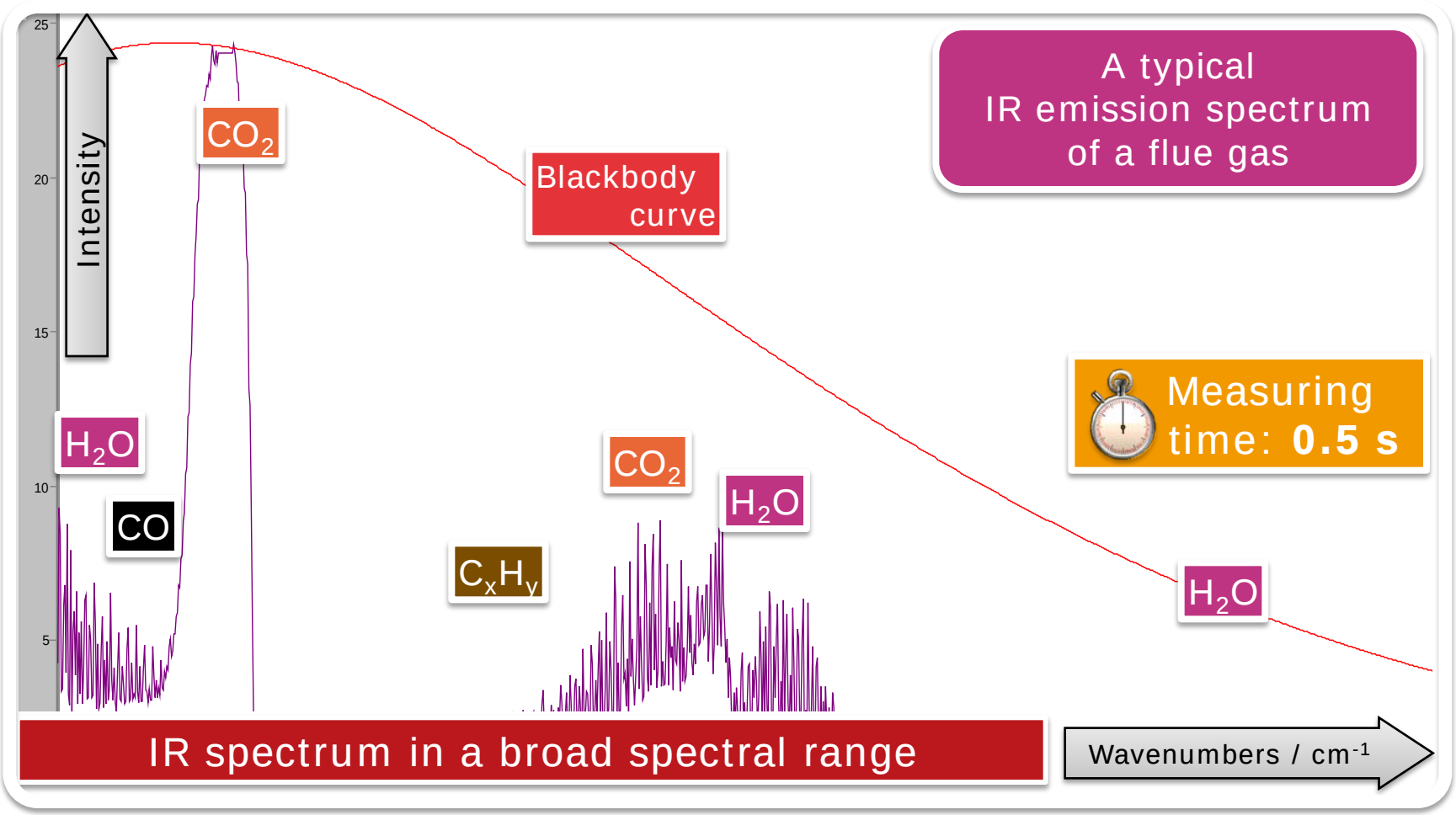


Measurements are possible under harsh conditions

- **IR emission probe**
  - a - infrared fibre
  - b - water-cooled stainless steel probe
  - c - optical mount
  - d - protection tube
  - e - water-cooled beam stop

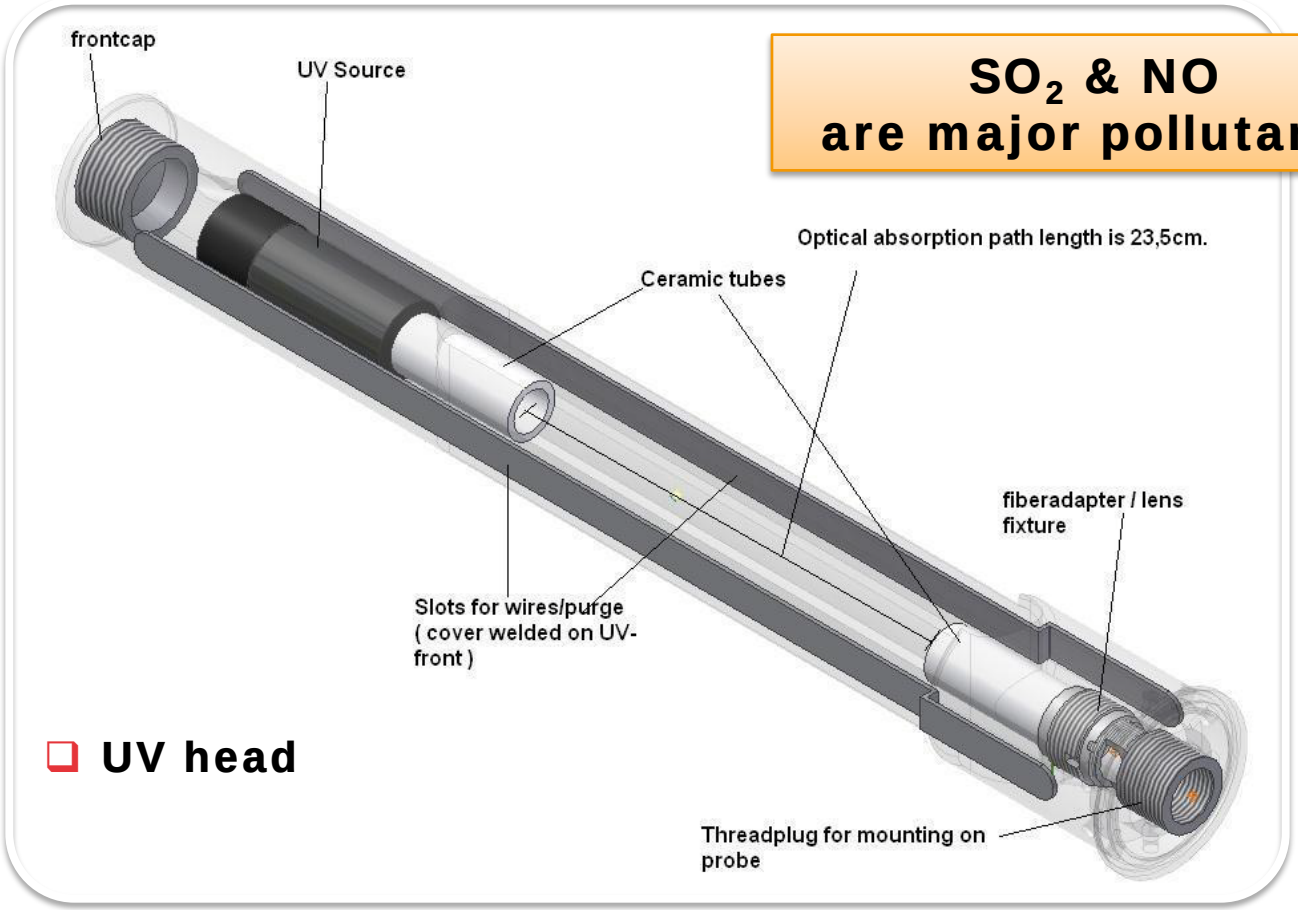
Allows to measure **temperature** **concentration** of H_2O CO_2 CO C_xH_y HCl etc.

Example of an IR emission spectrum

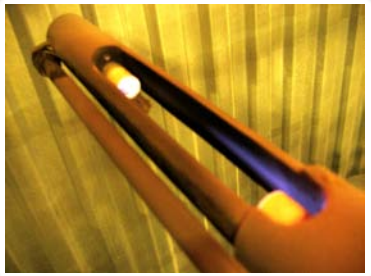


- Use of FTIR spectroscopy instead of e.g. laser spectroscopy allows to measure IR emission/absorption spectra in a broad spectral range within half a second

Optical instrumentation



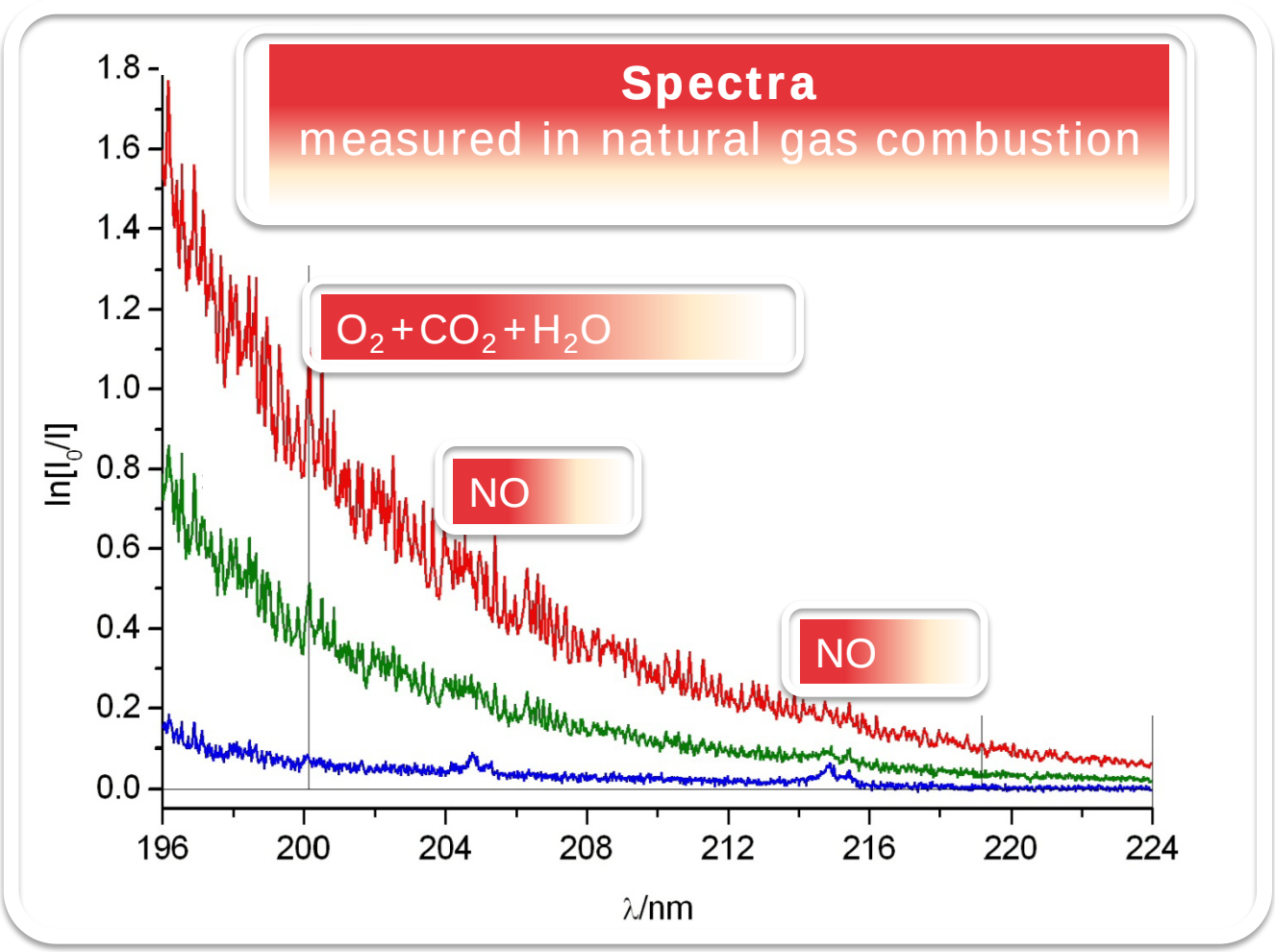
SO_2 & NO are major pollutants



- **UV head**

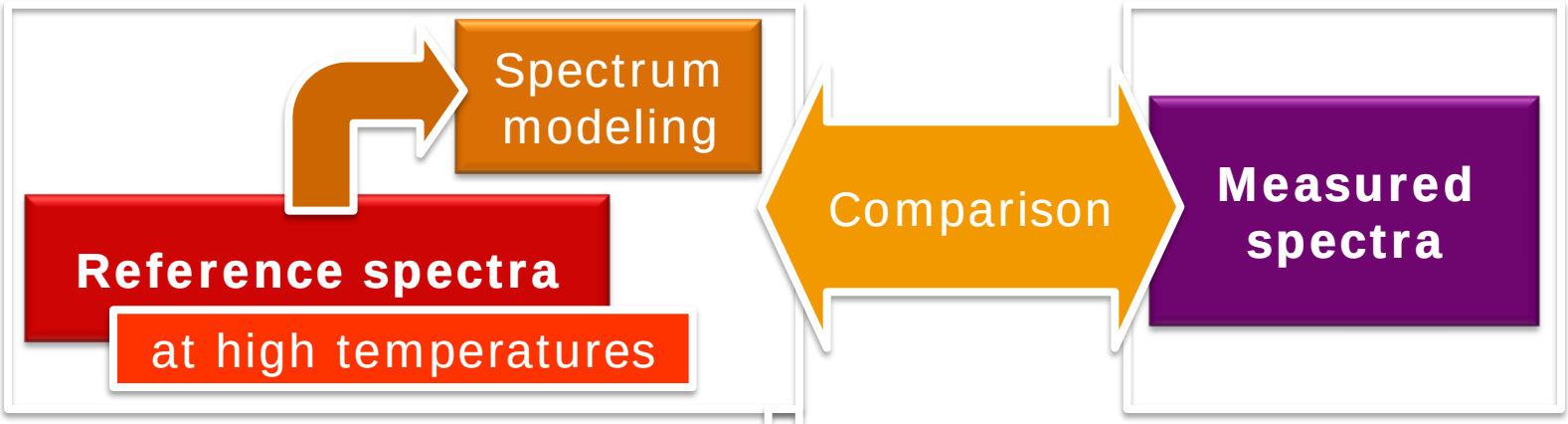
Allows to measure temperature concentration of SO_2 NO O_2 etc.

Example of an UV absorption spectrum

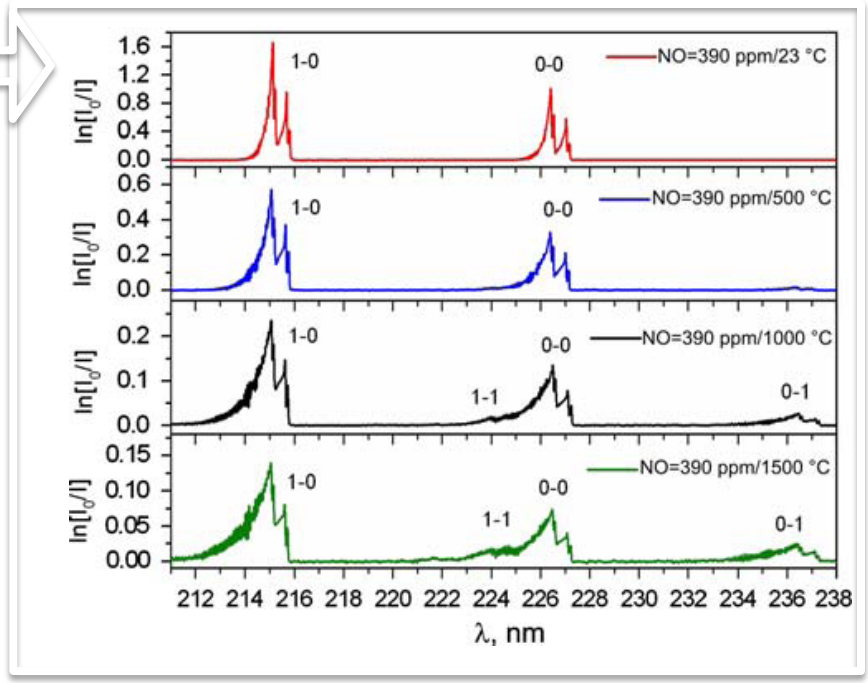


- NO, O_2 and SO_2 have their unique absorption features in the UV region

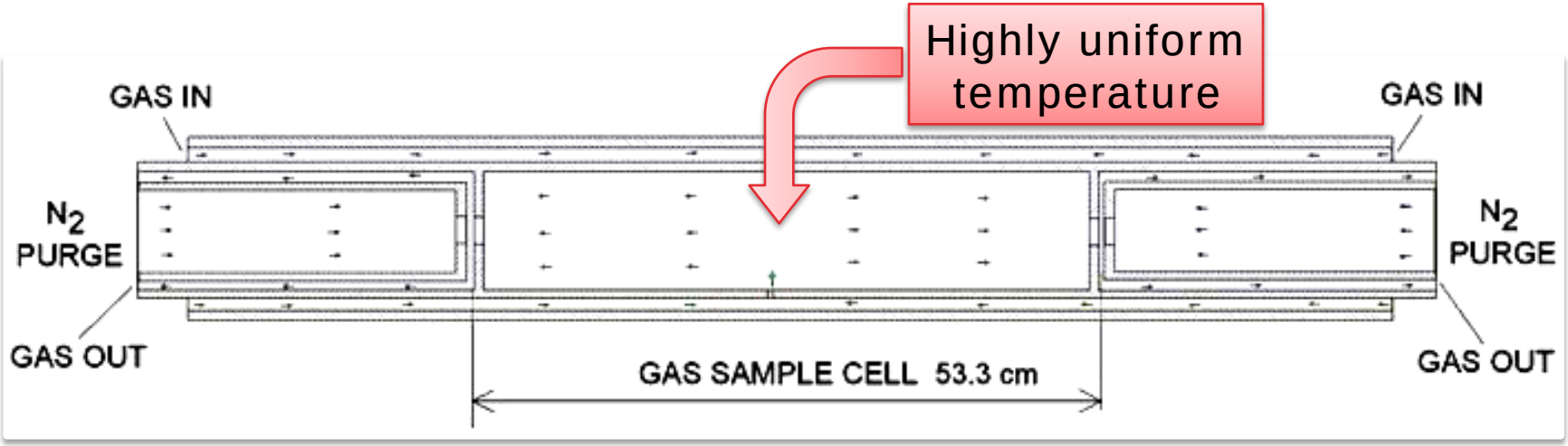
Hot gas cells

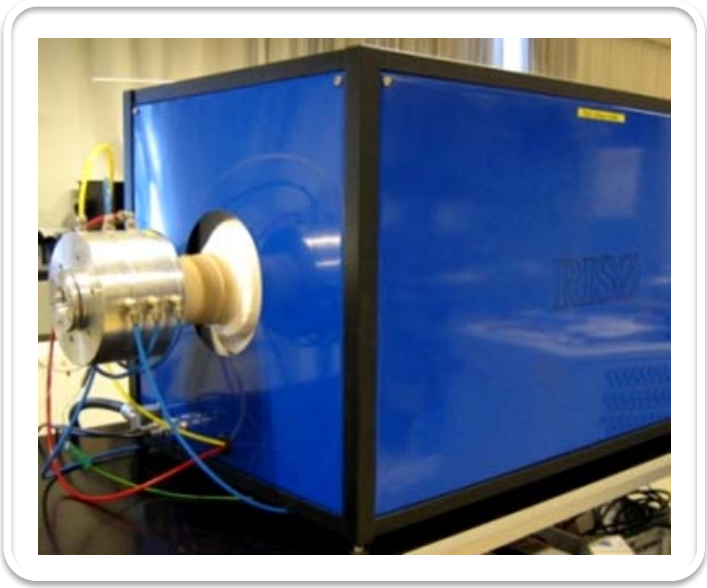


- **Uniform gas slabs at given temperatures are reproduced in specially designed gas cells**
- This allows
  - to validate spectra modeling databases at high temperatures
  - to provide spectra of gaseous species those are not available from known databases
  - to validate newly developed instrumentation for non-contact gas analysis



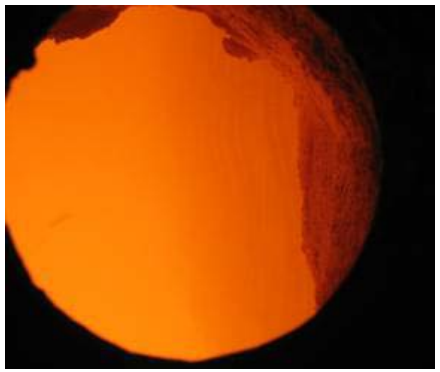
Ceramic hot flow gas cell (HGC)

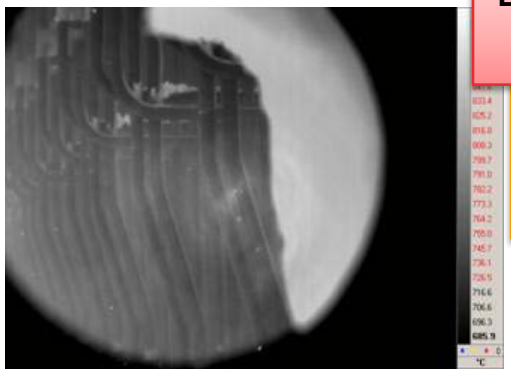




Temperature range	20 – 1600 ºC
Pressure range	Approx. 1 bar abs
Optical path	53.3 cm
Spectral region	From 200 nm (UV) to 10 µm (IR)

New diagnostic tools:
Fast IR imaging I





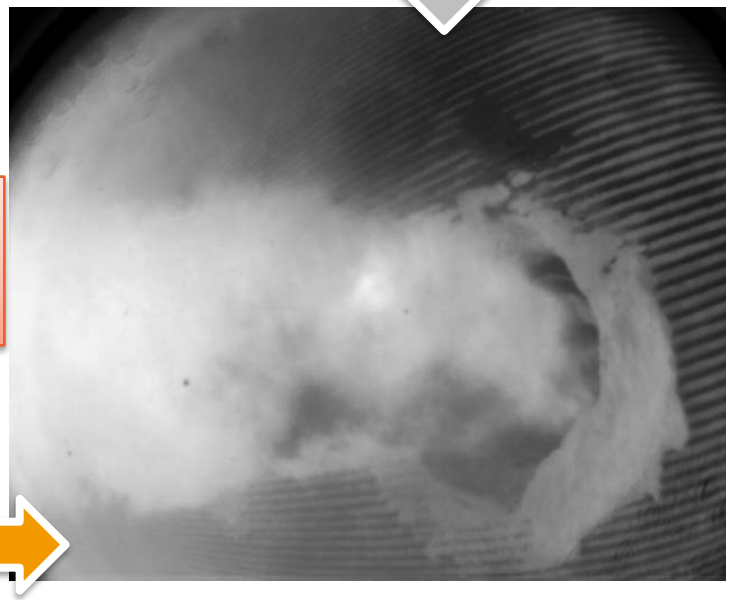
- Visual and thermal picture of a super-heater of a boiler

Exposure: **333 µs**

Delay between frames: **10 ms**

Frame rate: **90 images/s**

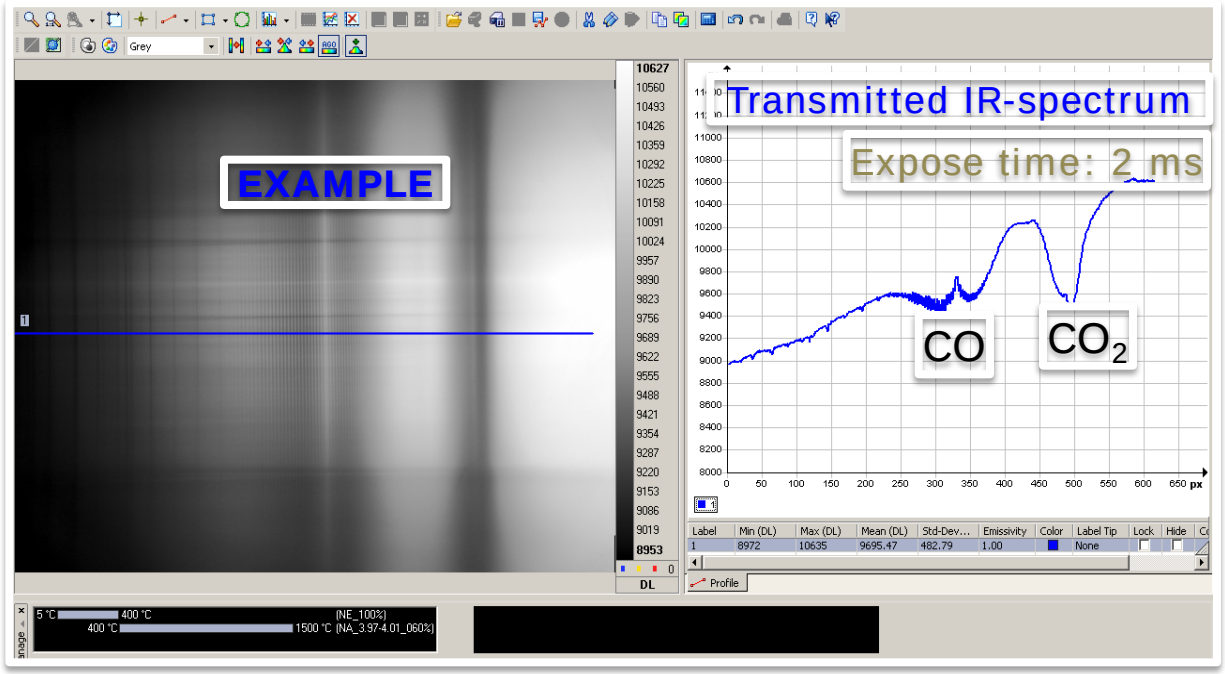
- Thermal picture of a burner of a boiler



IR images made with IR Camera = Endoscope + CEDIP camera

New diagnostic tools:
Fast IR imaging II

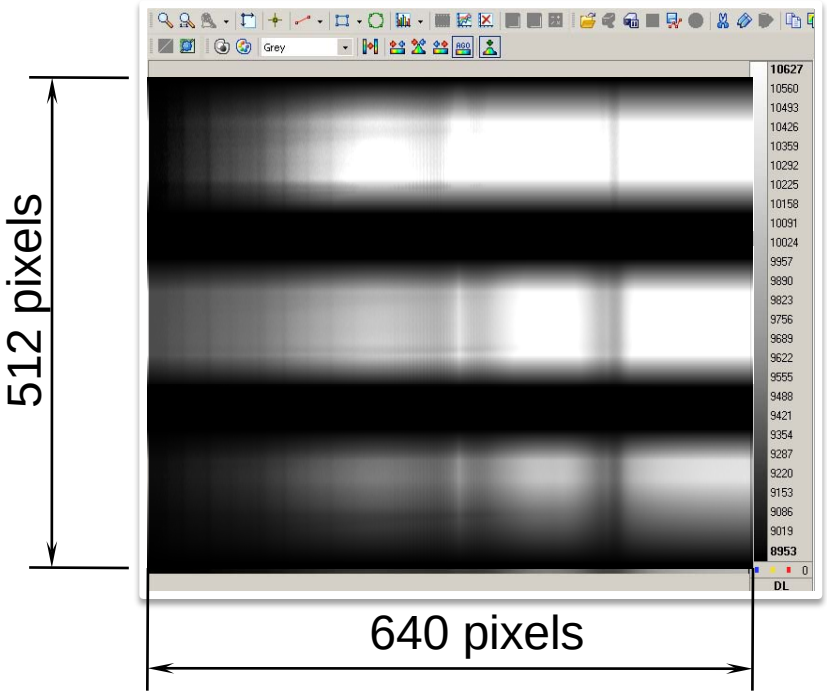
- ***In situ* fast IR absorption/emission spectroscopy**
  - **ACTON spectrometer + CEDIP Camera (InSb 640x512 array)**
- It allows to accomplish measurements within a few microseconds
  - This gives an opportunity to trace the development of a combustion process in time providing useful information for better understanding of combustion phenomena

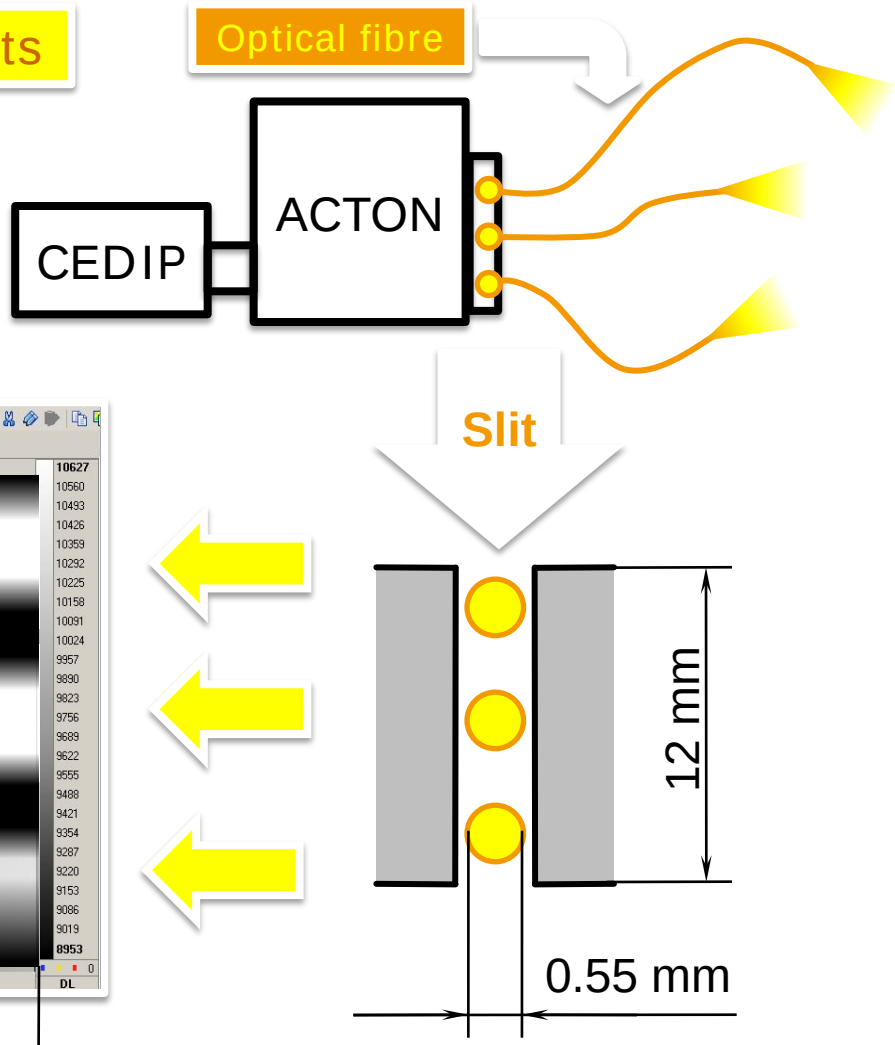


New diagnostic tools:
Multichannel Spectrometer

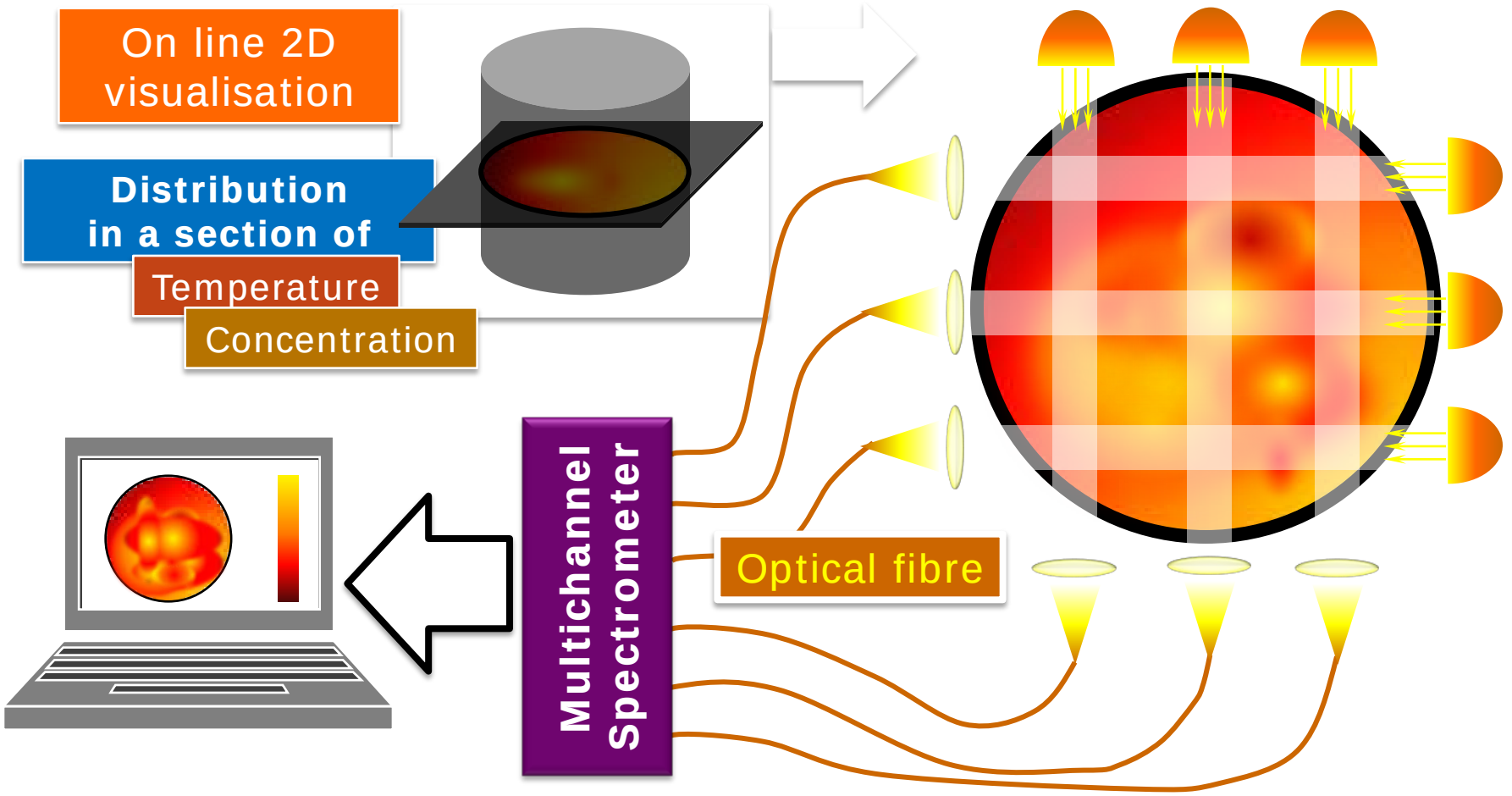
Simultaneous spectral measurements

- A multichannel assembly allows to perform spectral measurements simultaneously from several positions





New diagnostic tools:
2D Tomography



- 2D Tomography of e.g. hot gas inside of an exhaust pipe shows distribution of temperature or concentrations in a pipe section

Summary

- **Optically-based techniques developed at Risø make possible to carry out on-line optical measurements of**
  - gas and particle temperatures
  - concentration of gaseous species
- **These are achieved by**
  - measurements of the emission or absorption spectra of gases in UV- and/or IR-ranges
  - availability of high quality reference spectra for the species of interest either measured in one of Risø's hot gas cells or calculated with use of known and validated databases
  - post-processing of the acquired spectra
- **Spectral measurements can be performed**
  - within sufficiently short period of time
  - at various points inside a combustion unit
- **Risø's techniques give further opportunities to trace the development of a combustion process in time and space**
  - providing useful information for better understanding of the combustion phenomena

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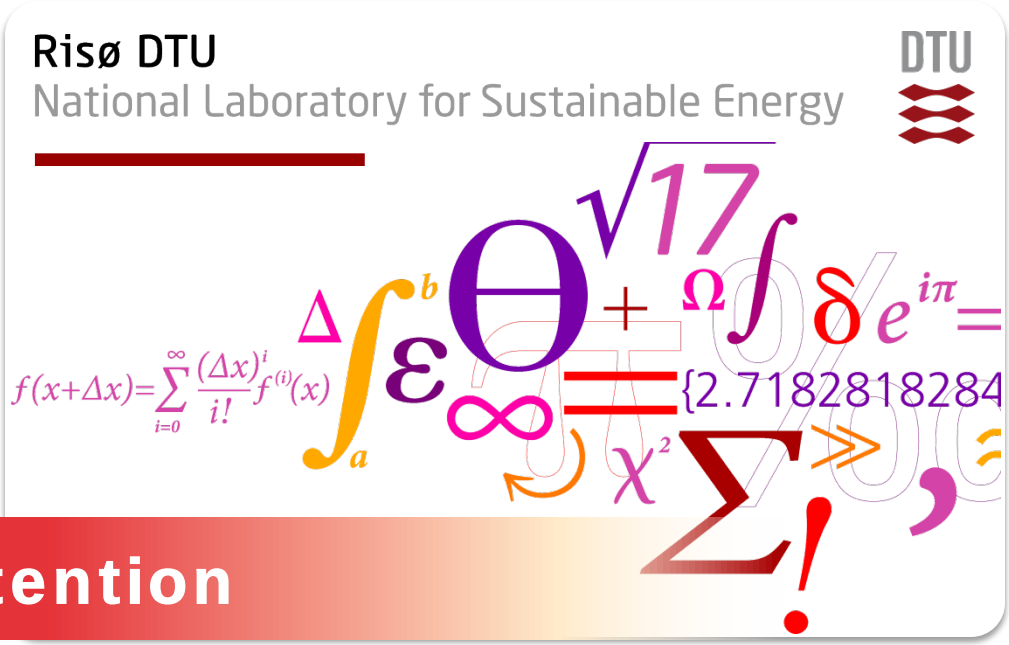

Thanks for your attention